Cassiar TSA inventory audit

Introduction

The Ministry of Forests conducts an inventory of each timber supply area (TSA) in British Columbia every 10 to 30 years—using standards and procedures developed by the Resources Inventory Program. Regular updates are undertaken to reflect changes in the timber volume due to growth and to depletions from harvesting and natural causes.

This report presents the results of an inventory audit performed within the Cassiar TSA, which is located in the northern portion of the Prince Rupert Forest Region in northwestern British Columbia. The Cassiar TSA covers approximately 13.4 million hectares. Although the Cassiar TSA is the largest in the province, much of the area is characterized by mountainous topography, thin soils, and harsh climate, and only a relatively small proportion of the total area is productive forest land. The Cassiar TSA is administered from the Bulkley/Cassiar Forest District office in Smithers.

Purpose of the audit and application of the results

It is often asked, "How accurate is the current inventory?" To answer this important question, the Ministry of Forests has developed an inventory audit methodology specifically designed to test the overall accuracy of estimates of the total standing volume in each timber supply area.

This inventory audit methodology entails sampling three primary components of the inventory: mature forests, immature forests, and non-forest areas.

The objective of the inventory audit program is to help identify TFLs or TSAs where the forest inventory needs attention. Enough samples are taken to ensure statistically reliable results for the TSA as a whole.

The amount of data collected, however, is not sufficient to make statistically reliable conclusions about specific areas or tree species. For example, any overall differences highlighted by the audit could result from problems with one tree species, from part of the land base (such as high elevation rather than lower elevation areas), from one age group of forest stands, or from a combination of these and other factors. As a consequence, general audit results cannot appropriately be used to adjust information about the forests currently available for timber harvesting since this area constitutes only a portion of the total forested area in the TSA.

The audits provide information that may be useful to the Chief Forester when determining the allowable annual cut—offering a general assessment of the uncertainty associated with mature timber volumes, immature site index, and the non-forest classification. However, the audit results cannot justifiably be used to make specific adjustments to growth and yield and other information used in timber supply analyses and allowable annual cut determinations.

Methods

Current inventory

There are 37 TSAs in British Columbia, varying in size from approximately 70 000 hectares to 13 million hectares. Inventories of each TSA are conducted through a multistage process. Polygons are first delineated from 1:15 000-scale aerial photographs. Photo-interpretation is then used to produce data on a number of attributes for each polygon. These attributes include species composition, stand height, age, and crown closure. Timber volume is then estimated indirectly using the photo-interpreted variables and an empirical yield model.

To keep estimates current, inventories are regularly updated to account for forest growth and for depletions due to harvesting, fire, and the impact of insects and disease damage. Empirical yield models, such as the Ministry of Forests Variable Density Yield Prediction (VDYP) computer model, are used to update the inventory for forest growth. Field visitation,

satellite imagery, and aerial photographs may be used to update the inventory for depletions.

Inventory audit procedures

The inventory audit tests three components of the current inventory. The first component is the mature forested areas (forest stands older than 60 years). The inventory audit tests the accuracy of the mature timber volume. The second component tested is immature stands (younger than 60 years but older than the silvicultural classification of free growing). The audit tests the accuracy of the site growth potential (site index) assignment for these stands. The third component tested is the area classified as non-forest in the inventory, which includes areas such as lakes, gravel pits, and alpine meadows. The audit tests the accuracy of the photo-interpreted classification for this component.

Mature component assessment criteria

To test the mature component of the inventory, the existing inventory's estimate of the mean mature volume per hectare for the TSA (*the inventory volume*) is compared with a new estimate of the mean mature volume per hectare obtained from the audit samples (*the audit volume*).

The difference between these two estimates is called the total bias. A test is conducted on this bias to determine if it is statistically significant. This test establishes whether there are detectable differences between the audit volume estimate and the inventory volume estimate, for the total forested area of the TSA.

If the total bias is found to be statistically significant, further analyses are conducted to determine if the specific source of bias within the inventory is one of the following:

- *classification bias:* This is caused by incorrectly estimating the polygon attributes; or
- *model bias:* This is caused by poor prediction from the yield model, which was developed for large areas of the province and was not designed for specific management units.

The analysis to determine the source of bias uses an estimate of the mean mature volume per hectare for the TSA called the *ground attribute volume*. This is calculated from audit sample attributes (stock and stand table estimates of species composition and stocking, and ground-based averages of top height and age), along with crown closure taken from the original map label, using the yield prediction model. The difference between the ground attribute volume estimate and the audit volume estimate approximates the bias associated with the yield model. The difference between the audit volume estimate and the inventory volume estimate not accounted for by the model bias approximates the bias associated with the inventory classification attributes. Once the source of bias is identified, further analyses may be done on the inventory classification attributes or the yield model itself.

Immature component assessment criteria

Accuracy of the inventory classification for immature stands is tested by examining the site index assignment. Since the immature forest stand site index provides an estimate of site productivity, its accuracy affects the projection of long-term harvest levels.

Data gathered is examined to determine how closely the audit and inventory site indices match for individual samples, and to explore potential trends.

Non-forest component assessment criteria

The audit test for the non-forest component of the inventory assesses the accuracy of the non-forest classification assignment. An airphoto interpreter certified by the Ministry of Forests compares the non-forest inventory classification to a suitably-scaled forest cover aerial photograph. Classification accuracy is rated using a point scoring scheme to determine an overall accuracy percentage. The acceptance criteria for this test is 85% or higher.

Cassiar TSA audit sampling procedures

The sampling design for the Cassiar TSA inventory audit was modified to accommodate the large size of the TSA. The sample size for the mature forested component of the inventory was increased to 70 polygons. The TSA was stratified into operable and inoperable areas, and the operable area was further divided into Dease Lake North and Dease Lake South, so that a total of three strata were identified.

1. Dease Lake North

   The Dease Lake North stratum encompasses the operable area within the Dease–Liard and Atlin Timber Supply Blocks. The predominant forest types in this area are lodgepole pine and black spruce.

2. Dease Lake South

   The Dease Lake South stratum includes the operable area within the Iskut and Boundary Timber Supply Blocks and is characterized by hemlock and balsam forest types.

3. Inoperable areas in the TSA

   The inoperable stratum comprises the greatest area within the TSA, including the Alsek and Kechika Timber Supply Blocks and the inoperable land base within the Atlin, Dease–Liard, Boundary, and Iskut Timber Supply Blocks.

The sampling strata used for the Cassiar TSA inventory audit are illustrated in Figure 1.

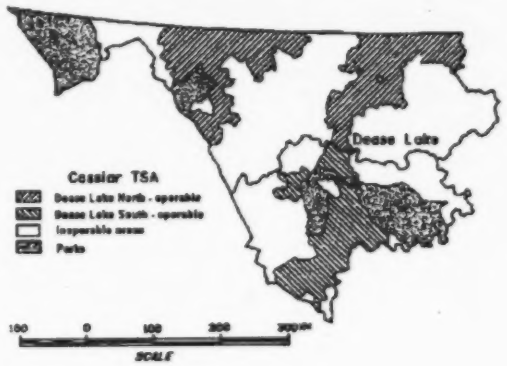


Figure 1. Map of inventory audit sampling strata, Cassiar TSA

The 70 audit samples were allocated disproportionately among the strata so that more samples were assigned to the operable Dease Lake North and South strata: 37 samples in Dease Lake North, 21 samples in Dease Lake South and 12 samples in the inoperable stratum. The allocation of samples between Dease Lake North and South differs from the originally proposed sample design, but this does not affect the analysis.

The Cassiar TSA sample used updated maps based on an inventory originally conducted between 1970 and 1975. For the mature forested component of the inventory audit within each stratum, a list of all polygons identified on the inventory maps was produced and sorted on a number of stand characteristics (site quality, age, and species group). Polygons were systematically selected from this list by a process designed to produce a representative sample in each stratum.

Up to 4 full-measure prism plots and 5 count plots were established within each of the 70 sample polygons. The plots were located systematically, using a square grid and a random start point. The grid interval varied with polygon size. To reduce sample costs for large or irregular polygons, only a randomly selected portion of the polygon was sampled. A total of about 280 full-measure and 350 count plots were established. Field data collection and compilation followed Ministry of Forests cruising and cruise compilation procedures. The objective was to obtain audit volumes that were comparable (in terms of utilization standards and merchantability definitions) to the inventory volumes produced from the VDYP computer yield model.

The VDYP system produces net merchantable volume per hectare defined as stem volume inside bark of all live trees excluding a 10-cm diameter inside-bark top, a 30-cm-high stump, and decay (as estimated from Ministry loss factors). Dead potential and veteran trees are not included in the VDYP estimates. This volume is calculated for a utilization standard defined as all live trees of 12.5+ cm dbh. When considering the audit results, it should be noted that there are some differences between the utilization standards applied in the audit and those used operationally.

The audit volume estimates were then compared to the inventory volume estimates (from VDYP) to test the validity of the current inventory. A paired-sample *t*-test was used to test for significant differences. The precision of the inventory volume estimates—how well each inventory volume estimate corresponds to the audit volume estimate on a sample-by-sample basis—was assessed by measuring the statistical correlation.

From the immature forested component, a random sample of 20 polygons was selected for sampling. Up

to 9 inventory ground calls were established within each of the 20 sample polygons. The plots were located systematically, using a square grid and a random start point, similar to the mature volume component. A total of about 180 ground calls were established and data collection followed the standard Ministry of Forests inventory ground call procedures.

To audit the non-forest component, a random sample of 32 non-forest polygons was selected. Standard Ministry of Forests inventory airphoto classification techniques were used to compare the 32 non-forest polygon classification assignments to corresponding airphoto checks.

Inventory audit results

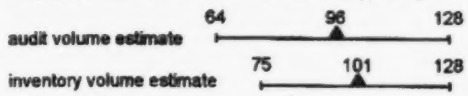
Analysis of mature volumes in the Cassiar TSA

Overall results of the inventory audit for mature volume in the total forested area of the Cassiar TSA are summarized at the 12.5+ cm dbh utilization limit in Table 1. The summary statistics reported in Table 1 are based on the means and variances within each stratum, weighted to account for the different size and sampling intensity within each stratum. The summary statistics for the TSA as a whole are greatly influenced by the inoperable stratum, which accounts for more than 50% of the productive Crown forest.

TABLE 1: Statistics for the audit volume and inventory volume estimates at 12.5+ cm dbh utilization (net decay), overall results, Cassiar TSA

	Audit volume estimate	Inventory volume estimate
Number of samples	70	70
Mean (m^3/ha)	96	101
Standard error	16.0	13.3
Sampling error (%)	33.2	26.2
95% confidence interval	64–128	75–128

Bar graph representation of 95% confidence intervals (in m^3/ha):



Due to the size of the TSA, more focus was placed on the strata results, and these are described in detail in the sections that follow.

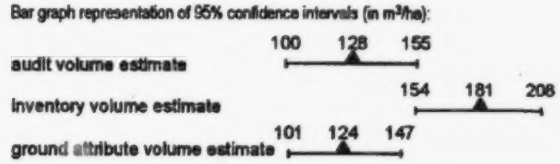
Analysis of mature volumes in Dease Lake North

Results of the inventory audit for mature volume in the Dease Lake North stratum of the Cassiar TSA are summarized at the 12.5+ cm dbh utilization limit in Table 2.

TABLE 2: Statistics for the audit volume, inventory volume, and ground attribute volume estimates at 12.5+ cm dbh utilization (net decay), Dease Lake North, Cassiar TSA

	Audit volume estimate	Inventory volume estimate	Ground attrib volume estimate
Number of samples	37	37	36
Mean (m^3/ha)	128	181	124
Coefficient of variation (%)	65	44	55
Standard error	13.7	13.2	11.4
Sampling error (%)	21.8	14.8	18.7
95% confidence interval	100–155	154–208	101–147
Correlation coefficient	r = 0.527		
Ratio of means (audit/inventory):	0.70		

Bar graph representation of 95% confidence intervals (in m^3/ha):



The correlation coefficient of 0.527 for the audit and inventory estimates indicates a good relationship among the individual samples in this stratum. There is a 53 m^3/ha difference between the mean inventory estimate for mature volume (181 m^3/ha) and the audit estimate (128 m^3/ha). This difference is statistically significant 19 times out of 20 for the mature component of the total forested area of the Dease Lake North stratum of the Cassiar TSA.

Since there is a statistically significant difference between the two estimates, the ground attribute volume was calculated using the VDYP model. Top height was not available for one sample; therefore the ground attribute volume estimates are based on 36

samples. The estimated mean ground attribute volume is 124 m^3/ha.

The difference between the mean ground attribute volume (124 m^3/ha) and the mean audit volume (128 m^3/ha) is 4 m^3/ha. The difference between the mean inventory volume (181 m^3/ha) and the mean ground attribute volume is 57 m^3/ha. This suggests that in the Dease Lake North stratum, a significant bias associated with the inventory attributes is being partially compensated for by a much smaller model bias in the opposite direction.

Further examination of the audit data shows that the mean estimated inventory height was almost 17% greater than the mean measured audit height in the Dease Lake North stratum. Since volume will be greatly influenced by height, this is a potential source of the volume overestimation observed in the audit of the Dease Lake North stratum.

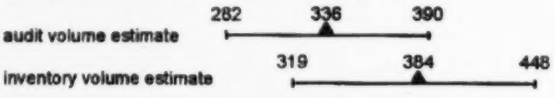
Analysis of mature volumes in Dease Lake South

Results of the inventory audit for mature volume in the Dease Lake South stratum of the Cassiar TSA are summarized at the 12.5+ cm dbh utilization limit in Table 3.

TABLE 3: Statistics for the audit volume and inventory volume estimates at 12.5+ cm dbh utilization (net decay), Dease Lake South, Cassiar TSA

	Audit volume estimate	Inventory volume estimate
Number of samples	21	21
Mean (m^3/ha)	336	384
Coefficient of variation (%)	35	37
Standard error	25.8	31.1
Sampling error (%)	16.0	16.9
95% confidence interval (m^3/ha)	282–390	319–448
Correlation coefficient	$r = 0.584$	
Ratio of means (audit/inventory)	0.88	

Bar graph representation of 95% confidence intervals (in m^3/ha)



The correlation coefficient of 0.584 for the audit and inventory estimates indicates a good relationship among the individual samples. There is a 48 m^3/ha difference between the mean inventory estimate for mature volume (384 m^3/ha) and the audit estimate (336 m^3/ha). This difference is not statistically significant 19 times out of 20 for the mature component of the total forested area of the Dease Lake South stratum of the Cassiar TSA.

Since there is no statistical difference between the two estimates, the ground attribute volume was not calculated.

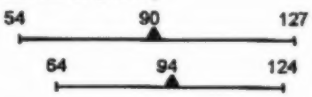
Analysis of mature volumes in the inoperable areas

Results of the inventory audit for mature volume in the inoperable areas of the Cassiar TSA are summarized at the 12.5+ cm dbh utilization limit in Table 4.

TABLE 4: Statistics for the audit volume and inventory volume estimates at 12.5+ cm dbh utilization (net decay), inoperable areas of the Cassiar TSA

	Audit volume estimate	Inventory volume estimate
Number of samples	12	12
Mean (m^3/ha)	90	94
Coefficient of variation (%)	64	51
Standard error	16.6	13.7
Sampling error (%)	40.4	32.2
95% confidence interval (m^3/ha)	54–127	64–124
Correlation coefficient	$r = 0.640$	
Ratio of means (audit/inventory)	0.96	

Bar graph representation of 95% confidence intervals (in m^3/ha)



The correlation coefficient of 0.640 for the audit and inventory estimates indicates a good relationship among the individual samples. There is a 4 m^3/ha difference between the mean inventory estimate for mature volume (94 m^3/ha) and the audit estimate (90 m^3/ha). A paired-sample *t*-test determined that, for the mature component of the total forested area in the

inoperable areas of the TSA, this difference is not statistically significant 19 times out of 20. However, due to the small sample size, these conclusions must be viewed with caution.

Since there is no statistical difference between the two estimates, the ground attribute volume was not calculated.

Analysis of immature inventory classification

Out of 20 stands sampled in the field, one stand was considered too young for an accurate site index assessment. Of the remaining 19 stands, the inventory correctly identified site index within ±3 m of the audit site index for 5 stands; the inventory site index was more than 3 m lower than the audit site index for 11 stands, and more than 3 m higher for 3 stands.

Analysis of non-forest inventory classification

Thirty-two stands classified as non-forest were assessed for accuracy of the inventory. The resulting score was 80%, which does not meet the provincial minimum standard of 85%.

Several factors should be considered in interpreting this result. In the past, little emphasis was placed on the actual delineation or description of some non-productive forest and non-forest types, as long as these types were not included in the productive land base. Generally, the polygons audited in the Cassiar TSA were correctly classified as non-productive or non-forest land. However, 31 of the 32 polygons selected for audit were very large alpine types and most contained treed areas with 10-20% crown closures. These areas should have been separated from the alpine and described as alpine forest types. In other cases, the alpine/alpine forest line should have been adjusted to incorporate more area in the existing alpine forest polygons.

In general, the polygon delineation of the non-forest and unproductive forest land was too general or rounded and did not follow the type boundaries accurately. In addition, four of the alpine polygons included regenerating old burns that should have been classified as not satisfactorily restocked, non-productive brush, unproductive immature forest, or, in several situations, productive immature forest.

The magnitude of the area incorrectly assessed as unproductive immature forest and the associated impact on the forested area available for timber supply is considered minimal.

Discussion and conclusions

The objective of the inventory audit in the Cassiar TSA was to assess the overall accuracy of the current (1970 to 1975) Ministry of Forests inventory. The mature, immature, and non-forest components were tested.

Audit results for the mature component of the inventory for the Cassiar TSA as a whole suggest that the inventory is acceptable. However, the overall results are highly influenced by the large size of the inoperable land base.

Audit results in the Dease Lake North (operable) stratum suggest that the inventory volume may be over-estimated in this area. The bias in the inventory volume estimates appears to be associated primarily with the current inventory attributes.

Audit results in the Dease Lake South (operable) stratum suggest that the inventory is statistically acceptable.

In the inoperable areas of the Cassiar TSA, the audit results suggest that the inventory is statistically acceptable. However, due to the small sample size in this stratum, these conclusions must be viewed with caution.

Audit results for the immature component suggest that the immature site index assignment may not be accurate in the Cassiar TSA. Further review of this component of the inventory is required.

The audit assessment of the non-forest classification in this TSA indicates that it did not meet provincial standards.

Glossary

accuracy: A measure of how close an estimate is to the true value.

allowable annual cut: The rate of timber harvesting specified for an area of land.

analysis unit: The basic building blocks around which inventory data and other information are organized for use in forest planning models, typically involving specific tree species or type

groups that are further defined by site class, geographic location or similarity of management regimes.

bias: The quality of a measurement device or procedures that tends to result in a systematic misrepresentation of what is being measured.

coefficient of variation: A relative measure of variation within a population, calculated as the ratio between the standard deviation and the mean value.

confidence interval: The range of values within which the population parameter is expected to lie.

confidence level: The estimated probability that a population parameter lies within a given confidence interval.

correlation coefficient: A measure of the relationship between two variables. A value of 0 for the correlation coefficient indicates a random relationship, whereas a value of ±1 indicates a perfect positive or negative linear correspondence.

dead potential trees: Standing or down dead timber which is estimated to contain at least 50% of its original gross volume in sound wood content.

diameter at breast height (dbh): The stem diameter (outside-bark) of a tree measured at breast height (1.3 metres above the point of germination) to the nearest millimetre.

field visitations: Ground-level field procedures designed to provide physical verification of polygon inventory attributes.

free-growing (crop): A crop of healthy trees of a commercially valuable species, the growth of which is not impeded by competition from plants, shrubs, or other trees.

inoperable lands: Lands that are unsuited for timber production now and in the foreseeable future because of their topography, inaccessible location, low value of timber stands, or designation for uses incompatible with timber production.

mean: The average value of a set of observations.

polygon: A portion of land area, delineated on mid-scale aerial photographs, of "like" or uniform land cover type.

pre-inventory assessments: Inventory activities to evaluate the existing forest inventory as a basis for deciding whether to re-inventory or update the current inventory, and to document the existing inventory, maps, and photos to support the execution of the reinventory or update if required.

public sustained yield units (PSYU): A portion of a TSA; an area of Crown land, usually a natural topographic unit determined by drainage areas, managed for sustained yield by the Crown through the Ministry of Forests. It includes all Crown lands within the currently established boundaries of the unit and excludes federal lands, provincial parks, experimental forest reserves, gazetted watersheds and tree farm licences.

ratio estimate: The ratio between two different estimates.

representative: The quality of a sample having the same characteristics as the population from which it is selected.

sampling: The process of selecting observations.

sampling error: The error attributed to sampling procedures.

significant difference: The results of a statistical test comparing either two or more estimates, or an estimate to a fixed value. If the difference is too large to be attributed to chance, the difference is said to be statistically significant.

site index: An expression of the forest site quality of a stand, at a specified age, based either on the site height, or on the top height, which is a more objective measure.

standard error: An expression of the absolute variability of an estimate.

standard deviation: A measure of the variation of the population.

timber supply analysis: An assessment of future timber supplies over long planning horizons (more than 200 years) by using timber supply models for

different scenarios identified in the planning process.

timber supply area (TSA): An area defined by an established pattern of wood flow from management units to the primary timber-using industries.

tree farm licence (TFL): Privately managed Sustained Yield Units; designed to enable owners of Crown-granted forest lands and old temporary tenures or the timber licences which replace them, to combine these with enough unencumbered Crown land to form self-contained sustained yield management units.

variable density yield prediction (VDYP) model: An empirical yield-prediction system for natural stands based on data collected in temporary inventory sample plots (TSPs) and natural, permanent growth sample plots (PSPs). VDYP predicts volume (net decay) and diameters at four utilization levels using stand height, age, and density. The aerial approach uses crown closure as the density measure.

veteran trees: Mature living trees which are remnants of an older stand.

For more information

For more information or to obtain other inventory audit reports, contact: Director, Resources Inventory Branch, 722 Johnson Street, Victoria, B.C., Canada V8W 3E7, 250-387-1314, fax 250-387-5999. Visit our web site at http:// www.for.gov.bc.ca/resinv/homepage.htm

December 1997

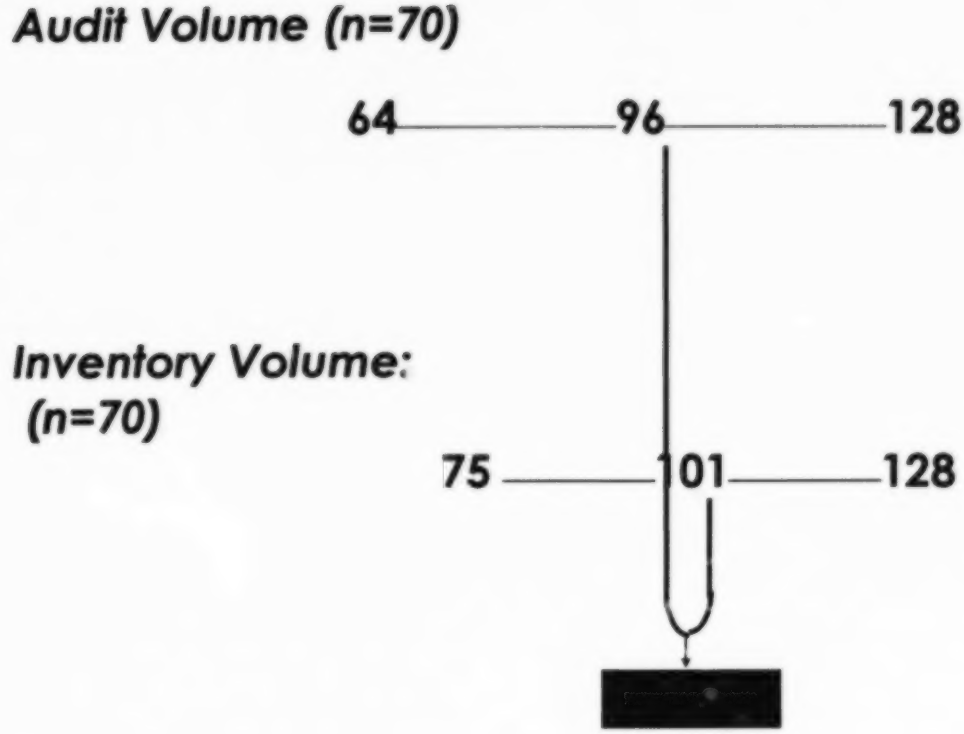
Inventory Audit Results:
Overview Cassiar TSA
September, 1997

Results for the Cassiar TSA 1
Immature Site Index and Classification Assessment 2
STRATUM RESULTS:
Dease Lake South 3
Total bias 4
"Model" bias 6
"Attribute" bias 8

Dease Lake North 10
Total bias 11
"Model" bias 13
"Attribute" bias 15
Audit height vs. Inventory height 17
Audit age vs. Inventory age 18

Inoperable 19
Total bias 20
"Model" bias 22
"Attribute" bias 24

Cassiar TSA*

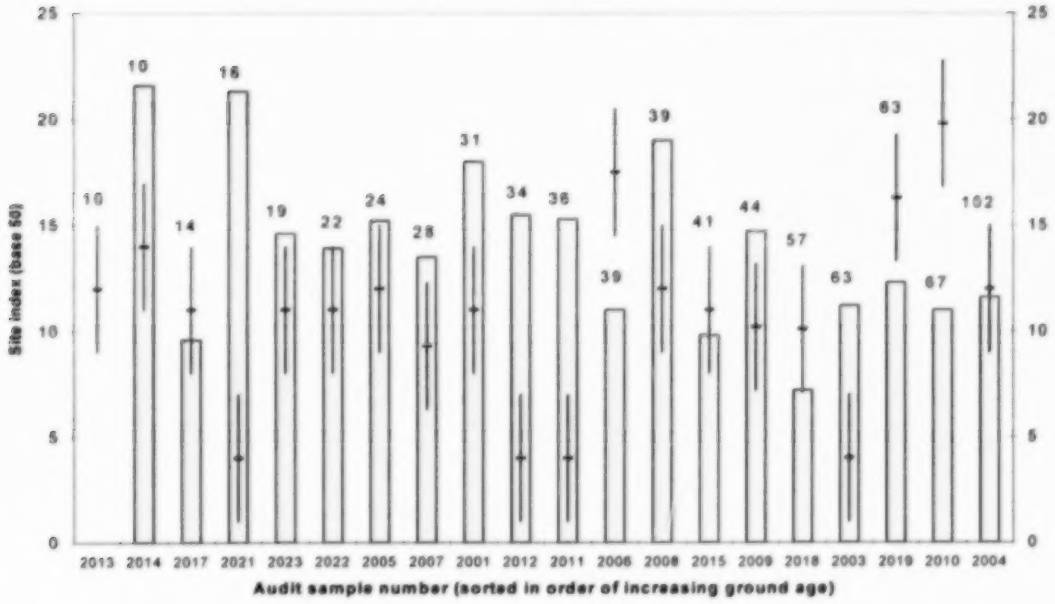


* A stratified sampling plan with disproportional allocation of the samples in each stratum was employed in the Cassiar TSA. The results here have been weighted by the appropriate stratum weights.

Immature Site Index and Classification Assessment*

- **45 %** of the growth type group assignments from the inventory (ie. map labels) matched the corresponding audit growth type group assignment.

CASSIAR TSA Inventory Audit:
Comparison of Inventory and Audit Site Index
for Immature Samples

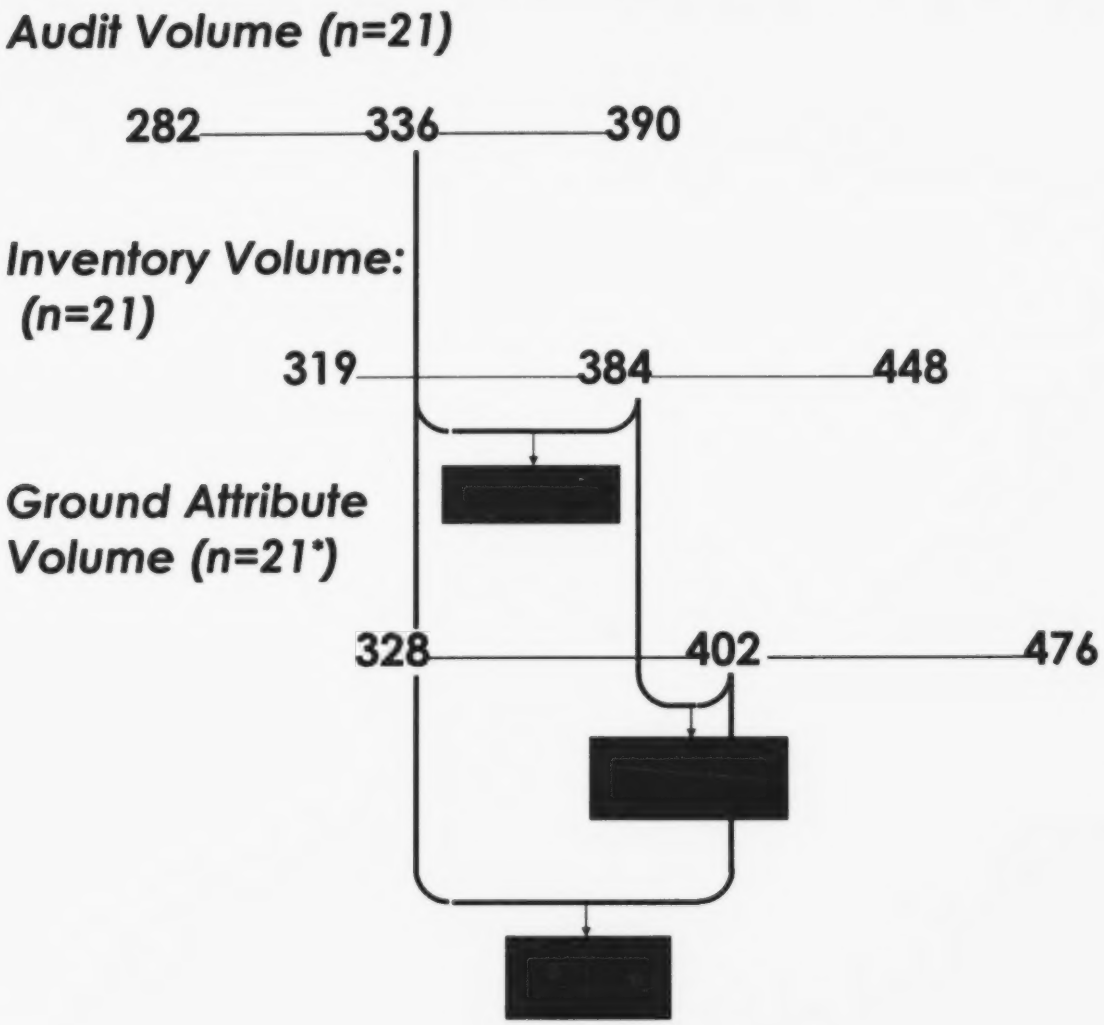


Notes:

- shaded bars correspond to ***audit site index*** values
- tick marks on vertical lines represent ***inventory site index*** (vertical lines have arbitrarily been set at ±3m around site index)
- numbers at the top of the bars corresponds to ground total age
- audit site indices based on BH age where available (using SiteTool)
- audit site index could not be computed for sample 2013 (TH<2m)
- inventory site index was within 3m of the audit site index for 5 out of 20 samples (inventory site index was more than 3m higher than the audit site index for 3 samples and more than 3m lower for 11 samples)
- TH species did not match inventory for 9 samples; alternate audit TH's were available for 5 of these; based on these, results were: 5 out of 20 within 3m; inventory SI high for 3 samples and low for 11 samples.

* These results are not weighted by stratum. There were immature samples in Dease Lake North, in Dease Lake South and in the economically inaccessible areas.

Dease Lake South



* "Ground attribute" volume is calculated from audit sample attributes (i.e. "ground" attributes: stock and stand table estimates of species composition and stocking, and ground-based averages of top height and age), along with crown closure taken from the original map label, using the VDYP yield prediction model. The difference between the ground attribute volume estimate and the audit volume estimate *approximates* the bias associated with the yield model. The difference between the ground attribute volume estimate and the inventory volume estimate *approximates* the bias associated with the inventory classification attributes. These two bias components comprise the *total bias* in the inventory.

Dease Lake South

Audit Volume (Kozak) vs. Inventory Volume (Predicted in VDYP) (n=21)

1. Average Volumes/ha and Confidence Interval @ 95% *(Utilization level : 12.5 cm + net merch. less decay only/Tree Class 1,2)*

282 ——— 336 ——— 390 Audit Volume (16.0% sampling error)

319 ——— 384 ——— 448 Inventory Volume (map label attributes predicted in VDYP) (16.9% sampling error)

2. Ratio Analysis : Ratio of Means @95%

$R = \frac{\text{average audit volume}}{\text{average inventory volume}} = 0.88$

1.0 ↓

0.75 ——— 0.88 ——— 1.01

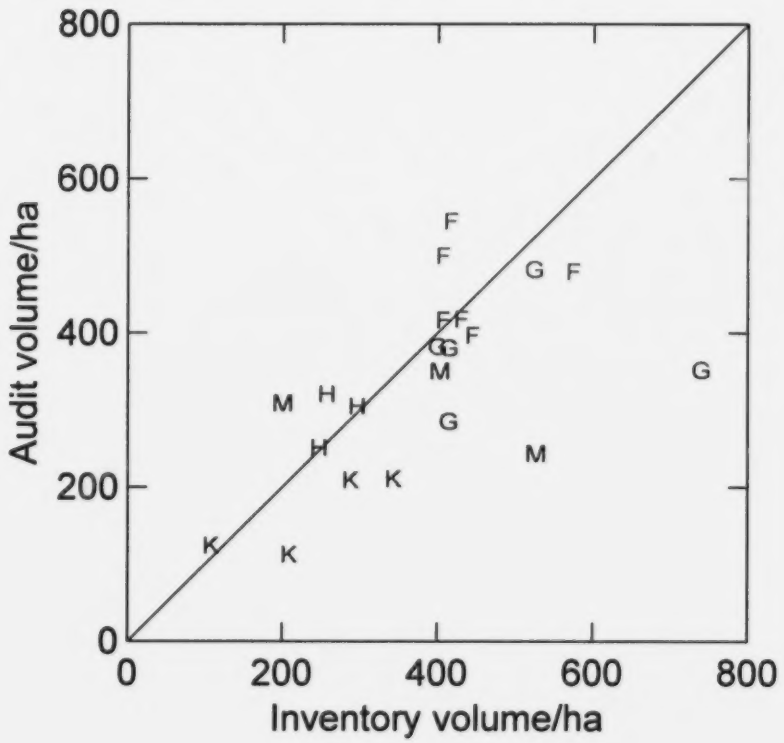
* *Since 1.0 is within the interval, the ratio indicates that there is no significant difference between the audit volume and the inventory volume.*

3. Paired T Test @ 95% (α=0.05) for all sample polygons
mean difference = -47.410 m^3/ha
p - value for mean difference = 0.088
**since p-value > α, the difference is not significant*

4. Paired T Test @ 95% for all sample polygons by map label GTG
There were no significant differences within any of the GTGs.

5. Correlation @ 95% (α=0.05) for all samples
Correlation co-efficient r = 0.584
p value for correlation co-efficient = 0.005
∴ correlation is significant

Cassiar TSA -- Dease Lake South:
Audit Volume vs. Inventory Volume (by GTG)
(Tree Class 1 & 2, less decay only, 12.5cm + dbh)



Letter symbols correspond to map label GTG's as follows:

F	*H, H Decid.*	K	*S Pl , S Decid.*
G	*HF,HL,HPy,HPw,HPl,HC,HB,HS*	L	*pure Pl or Pa*
H	*B, BH, BS,BF,BPw,BPl,BL,BPy,BDecid.*	M	*Pl F, Pl Py,Pl L,Pl Pw,Pl S,Pl B,Pl H,PlC*
I	*pure S*	N	*Pl Decid.*
J	*SF,SL,SPw,SPy,SH,SC,SB,SPl*	P	*Dr Decid, Mb, E, At Decid.*

Dease Lake South

Audit Volume (Kozak) vs. Ground Attribute Volume (Predicted in VDYP): "VDYP model" bias (n=21)

1. Average Volumes/ha and Confidence Interval @ 95% *(Utilization level : 12.5 cm + net merch. less decay only /Tree class 1,2))*

282 ——— 336 ——— 390

Audit Volume
(16.0% sampling error)

328 ——— 402 ——— 476

Ground Attribute Volume
(predicted in VDYP)
(18.4% sampling error)

2. Ratio Analysis : Ratio of Means @95%

$R =$ *average audit volume* / *average ground attribute volume predicted in VDYP* $= 0.84$

1.0 ↓

0.75 ——— 0.84 ——— 0.92

* *Since 1.0 is outside the interval, the ratio indicates that there is a significant difference between the audit volume and the ground attribute volume.*

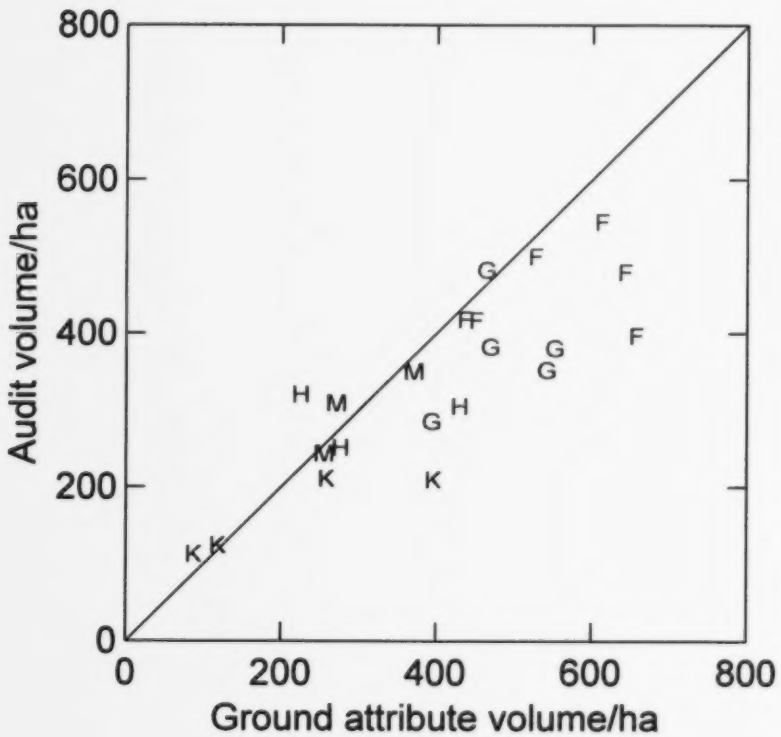
3. Paired T Test @ 95% ($\alpha = 0.05$) for all sample polygons
mean difference = -65.695 m^3/ha
p - value for mean difference = 0.003
**since p - value < α, the difference is significant*

4. Paired T Test @ 95% for all sample polygons by map label GTG
There was a significant difference within GTG G.
(for GTG G: mean difference = -108.58 m^3/ha; p-value=0.042; n=5)

5. Correlation @95%($\alpha = 0.05$) for all samples
Correlation co-efficient r = 0.837
p - value for correlation co-efficient < 0.001
.: correlation is significant

CASSIAR TSA -- Dease Lake South: Audit Volume (Kozak) vs. Ground Attribute Volume (Predicted in VDYP) by GTG

(Tree Class 1 & 2, less decay only, 12.5cm + dbh)



Letter symbols correspond to map label GTG's as follows:

F	*H, H Decid.*	K	*S Pl , S Decid.*
G	*HF,HL,HPy,HPw,HPl,HC,HB,HS*	L	*pure Pl or Pa*
H	*B, BH, BS,BF,BPw,BPl,BL,BPy,BDecid.*	M	*Pl F, Pl Py,Pl L,Pl Pw,Pl S,Pl B,Pl H,PlC*
I	*pure S*	N	*Pl Decid.*
J	*SF,SL,SPw,SPy,SH,SC,SB,SPl*	P	*Dr Decid, Mb, E, At Decid.*

Dease Lake South

Ground Attribute Volume (predicted in VDYP) vs. Inventory Volume (predicted in VDYP): "Attribute" Bias (n=21)

1. Average volumes/ha and confidence interval @ 95%
(Utilization level : 12.5 cm + net merch. less decay only, Tree Class 1,2))

328——————402——————476 Ground Attribute Volume
(predicted in VDYP)
(18.4% sampling error)

319——————384——————448 Inventory Volume
(map label attributes predicted in VDYP)
(16.9% sampling error)

2. Ratio Analysis : Ratio of Means @ 95%

$$R = \frac{\text{average ground attribute volume (VDYP)}}{\text{average inventory volume (VDYP)}} = 1.05$$

1.0
↓
0.90——————1.05——————1.20

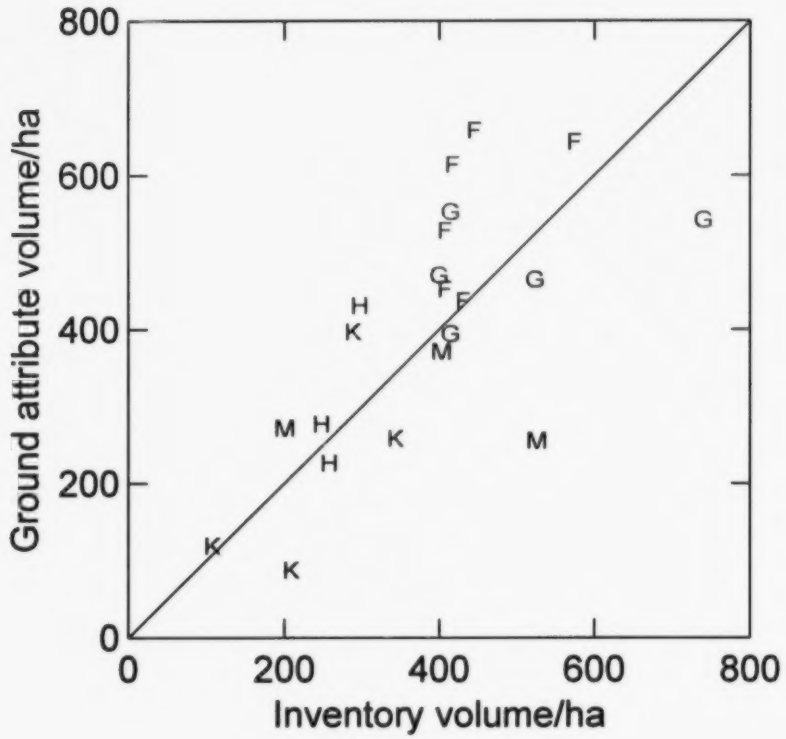
** Since 1.0 is within the interval, the ratio indicates that there is no significant difference between the ground attribute volume predicted in VDYP and the inventory volume predicted in VDYP.*

3. Paired T Test @ 95% ($\alpha = 0.05$) for all sample polygons
mean difference = 18.286 m^3/ha
p - value for mean difference = 0.500
**since p - value > α, the difference is not significant*

4. Paired T Test @ 95% for all sample polygons by map label GTG
There was a significant difference within GTG F.
(for GTG F: mean difference = 107.73 m^3/ha; p-value=0.025; n=6)

5. Correlation @95%($\alpha = 0.05$) for all samples
Correlation co-efficient r = 0.687
p - value for correlation co-efficient = 0.001
∴ correlation is significant

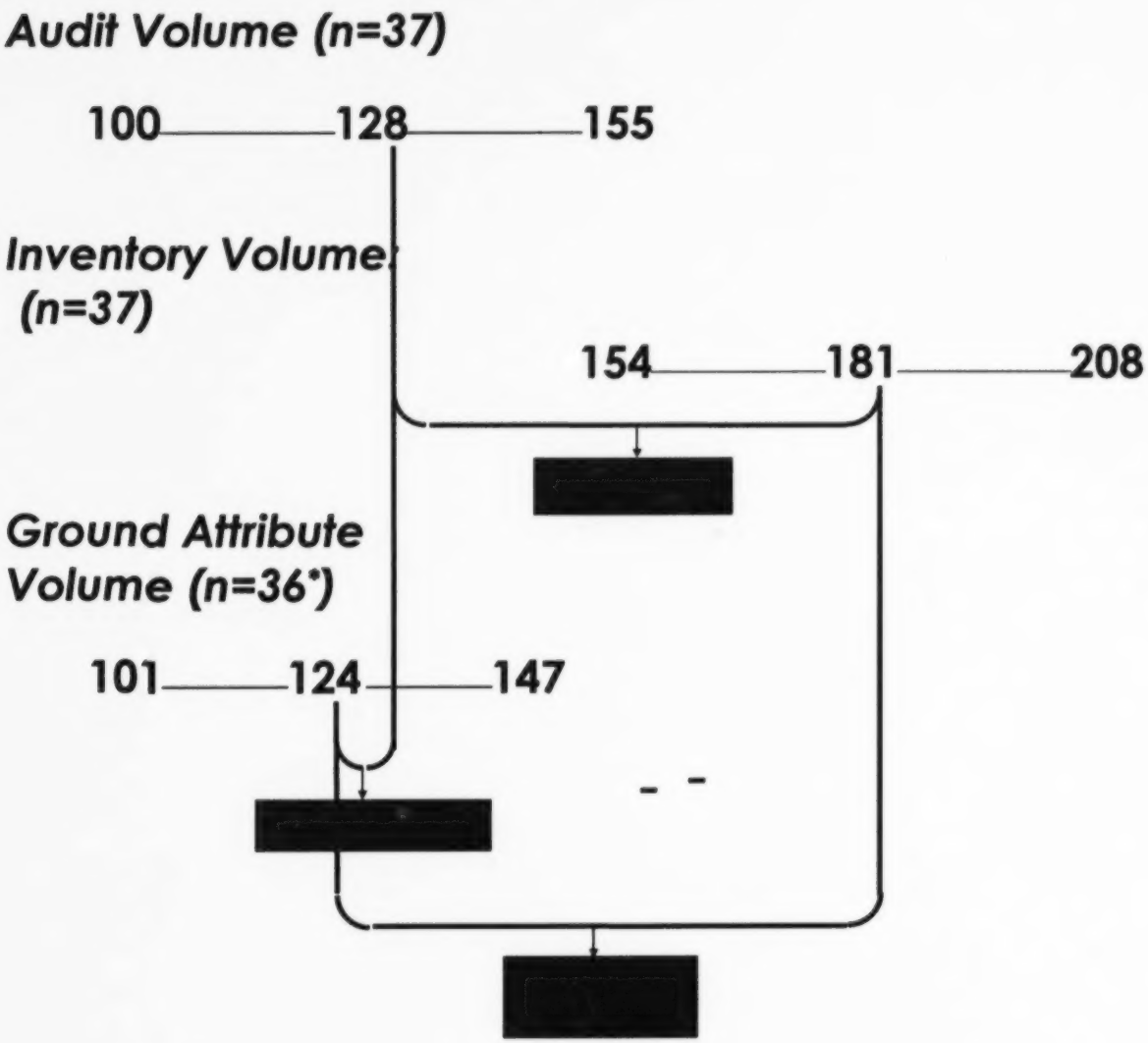
CASSIAR TSA -- Dease Lake South:
Ground Attribute Volume (Predicted in VDYP) vs. Inventory Volume (Predicted in VDYP) by GTG
(Tree Class 1 & 2, less decay only, 12.5cm + dbh)



Letter symbols correspond to map label GTG's as follows:

F	*H, H Decid.*	K	*S Pl , S Decid.*
G	*HF,HL,HPy,HPw,HPl,HC,HB,HS*	L	*pure Pl or Pa*
H	*B, BH, BS,BF,BPw,BPl,BL,BPy,BDecid.*	M	*Pl F, Pl Py,Pl L,Pl Pw,Pl S,Pl B,Pl H,PlC*
I	*pure S*	N	*Pl Decid.*
J	*SF,SL,SPw,SPy,SH,SC,SB,SPl*	P	*Dr Decid, Mb, E, At Decid.*

Dease Lake North



* Top height and age was not available for 1 sample, hence estimate for mean ground attribute volume is based on 36 samples only. "Ground attribute" volume is calculated from audit sample attributes (i.e. "ground" attributes: stock and stand table estimates of species composition and stocking, and ground-based averages of top height and age), along with crown closure taken from the original map label, using the VDYP yield prediction model. The difference between the ground attribute volume estimate and the audit volume estimate *approximates* the bias associated with the yield model. The difference between the ground attribute volume estimate and the inventory volume estimate *approximates* the bias associated with the inventory classification attributes. These two bias components comprise the *total bias* in the inventory.

Dease Lake North

Audit Volume (Kozak) vs. Inventory Volume (Predicted in VDYP) (n=37)

1. Average Volumes/ha and Confidence Interval @ 95% *(Utilization level : 12.5 cm + net merch. less decay only/Tree Class 1,2)*

100 ——— 128 ——— 155

Audit Volume
(21.8% sampling error)

154 ——— 181 ——— 208

Inventory Volume
(map label attributes predicted in VDYP)
(14.8% sampling error)

2. Ratio Analysis : Ratio of Means @95%

$$R = \frac{\text{average audit volume}}{\text{average inventory volume}} = 0.70$$

1.0
↓

0.57 ——— 0.70 ——— 0.84

* *Since 1.0 is outside the interval, the ratio indicates that there is a significant difference between the audit volume and the inventory volume.*

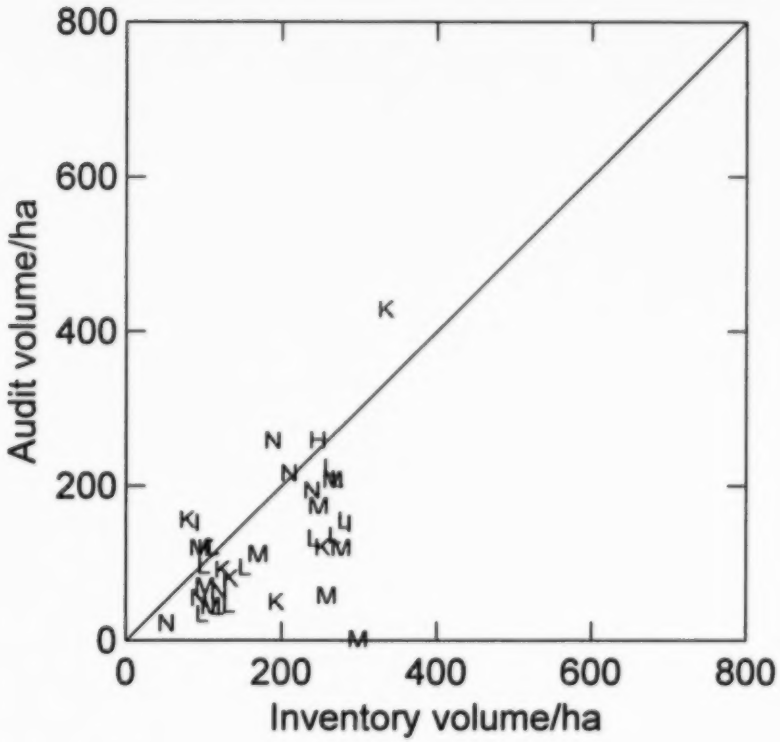
3. Paired T Test @ 95% (α=0.05) for all sample polygons
mean difference = -53.641 m^3/ha
p - value for mean difference < 0.001
**since p-value < α, the difference is significant*

4. Paired T Test @ 95% for all sample polygons by map label GTG
There were significant differences within GTGs L and M.
(for GTG L: mean difference = -61.21 m^3/ha; p-value=0.001; n=12
for GTG M: mean difference = -101.88 m^3/ha; p-value=0.015; n=9)

5. Correlation @ 95% (α=0.05) for all samples
Correlation co-efficient r = 0.527
p value for correlation co-efficient = 0.001
∴ correlation is significant

Cassiar TSA -- Dease Lake North: Audit Volume vs. Inventory Volume (by GTG)

(Tree Class 1 & 2, less decay only, 12.5cm + dbh)



Letter symbols correspond to map label GTG's as follows:

F	*H, H Decid.*	K	*S Pl , S Decid.*
G	*HF,HL,HPy,HPw,HPl,HC,HB,HS*	L	*pure Pl or Pa*
H	*B, BH, BS,BF,BPw,BPl,BL,BPy,BDecid.*	M	*Pl F, Pl Py,Pl L,Pl Pw,Pl S,Pl B,Pl H,PlC*
I	*pure S*	N	*Pl Decid.*
J	*SF,SL,SPw,SPy,SH,SC,SB,SPl*	P	*Dr Decid, Mb, E, At Decid.*

Dease Lake North

Audit Volume (Kozak) vs. Ground Attribute Volume (Predicted in VDYP): "VDYP model" bias (n=36*)

1. Average Volumes/ha and Confidence Interval @ 95% *(Utilization level : 12.5 cm + net merch. less decay only /Tree class 1,2))*

103——————**131**——————**159** Audit Volume (21.1% sampling error)

101——————**124**——————**147** Ground Attribute Volume (predicted in VDYP) (18.7% sampling error)

2. Ratio Analysis : Ratio of Means @95%

$$R = \frac{\text{average audit volume}}{\text{average ground attribute volume predicted in VDYP}} = 1.06$$

1.0
↓

0.92——————**1.06**——————**1.20**

* *Since 1.0 is within the interval, the ratio indicates that there is no significant difference between the audit volume and the ground attribute volume.*

3. Paired T Test @ 95% ($\alpha = 0.05$) for all sample polygons
   mean difference = 7.294 m^3/ha
   p - value for mean difference = 0.396
   **since p - value > α, the difference is not significant*

4. Paired T Test @ 95% for all sample polygons by map label GTG
   There were no significant differences within any of the GTGs.

5. Correlation @95%($\alpha = 0.05$) for all samples
   Correlation co-efficient r = 0.785
   p - value for correlation co-efficient < 0.001
   .: correlation is significant

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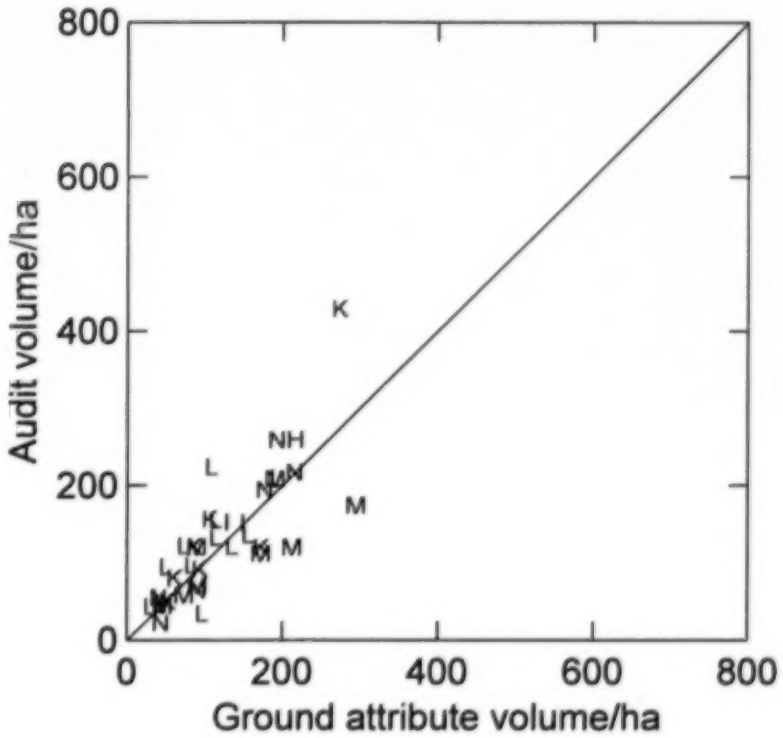
* Ground-measured top height and age (and hence ground attribute volume) was not available for one sample. All comparisons here are based on the 36 samples for which *both* an audit volume and a ground attribute volume were available.

CASSIAR TSA -- Dease Lake North:
Audit Volume (Kozak) vs. Ground Attribute Volume (Predicted in VDYP) by GTG
(Tree Class 1 & 2, less decay only, 12.5cm + dbh)



Letter symbols correspond to map label GTG's as follows:

F	*H, H Decid.*	K	*S Pl , S Decid.*
G	*HF,HL,HPy,HPw,HPl,HC,HB,HS*	L	*pure Pl or Pa*
H	*B, BH, BS,BF,BPw,BPl,BL,BPy,BDecid.*	M	*Pl F, Pl Py,Pl L,Pl Pw,Pl S,Pl B,Pl H,PlC*
I	*pure S*	N	*Pl Decid.*
J	*SF,SL,SPw,SPy,SH,SC,SB,SPl*	P	*Dr Decid, Mb, E, At Decid.*

Dease Lake North

Ground Attribute Volume (predicted in VDYP) vs. Inventory Volume (predicted in VDYP): "Attribute" Bias (n=36*)

1. Average volumes/ha and confidence interval @ 95%
(Utilization level : 12.5 cm + net merch. less decay only, Tree Class 1,2])

101——124——147 Ground Attribute Volume (predicted in VDYP) (18.7% sampling error)

151——178——205 Inventory Volume (map label attributes predicted in VDYP) (15.0% sampling error)

2. Ratio Analysis : Ratio of Means @ 95%

$$R = \frac{\text{average ground attribute volume (VDYP)}}{\text{average inventory volume (VDYP)}} = 0.70$$

1.0 ↓

0.59——0.70——0.80

** Since 1.0 is outside the interval, the ratio indicates that there is a significant difference between the ground attribute volume predicted in VDYP and the inventory volume predicted in VDYP.*

3. Paired T Test @ 95% ($\alpha = 0.05$) for all sample polygons
mean difference = -54.175 m^3/ha
p - value for mean difference < 0.001
**since p - value < α, the difference is significant*

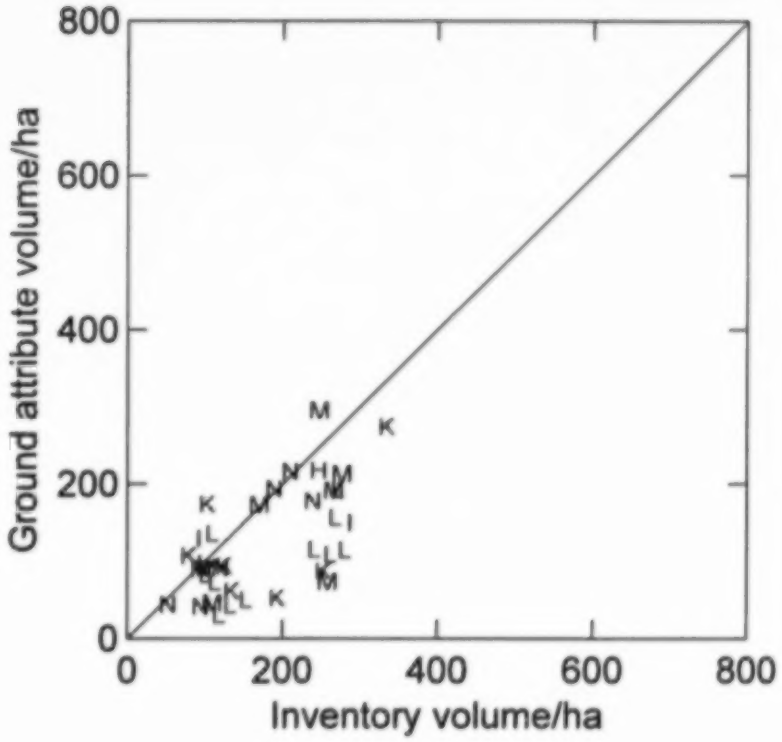
4. Paired T Test @ 95% for all sample polygons by map label GTG
There was a significant difference within GTG L.
(for GTG L: mean difference = -79.17 m^3/ha; p-value=0.001; n=12)

5. Correlation @95%($\alpha = 0.05$) for all samples
Correlation co-efficient r = 0.609
p - value for correlation co-efficient < 0.001
∴ correlation is significant

---

* Ground-measured top height and age (and hence ground attribute volume) was not available for one sample. All comparisons here are based on the 36 samples for which *both* an inventory volume and a ground attribute volume were available.

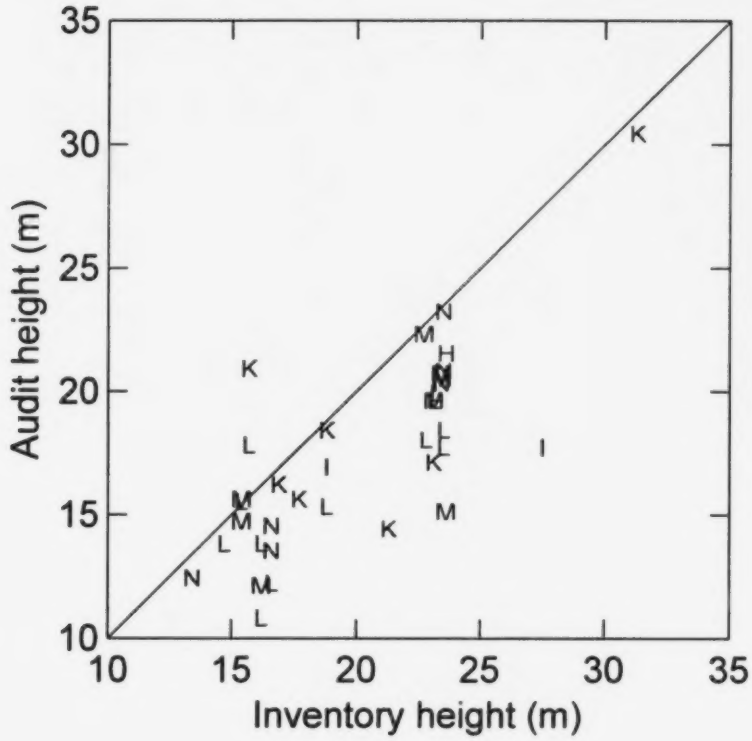
CASSIAR TSA -- Dease Lake North:
Ground Attribute Volume (Predicted in VDYP) vs. Inventory Volume (Predicted in VDYP) by GTG
(Tree Class 1 & 2, less decay only, 12.5cm + dbh)



Letter symbols correspond to map label GTG's as follows:

F	*H, H Decid.*	K	*S Pl , S Decid.*
G	*HF,HL,HPy,HPw,HPl,HC,HB,HS*	L	*pure Pl or Pa*
H	*B, BH, BS,BF,BPw,BPl,BL,BPy,BDecid.*	M	*Pl F, Pl Py,Pl L,Pl Pw,Pl S,Pl B,Pl H,PlC*
I	*pure S*	N	*Pl Decid.*
J	*SF,SL,SPw,SPy,SH,SC,SB,SPl*	P	*Dr Decid, Mb, E, At Decid.*

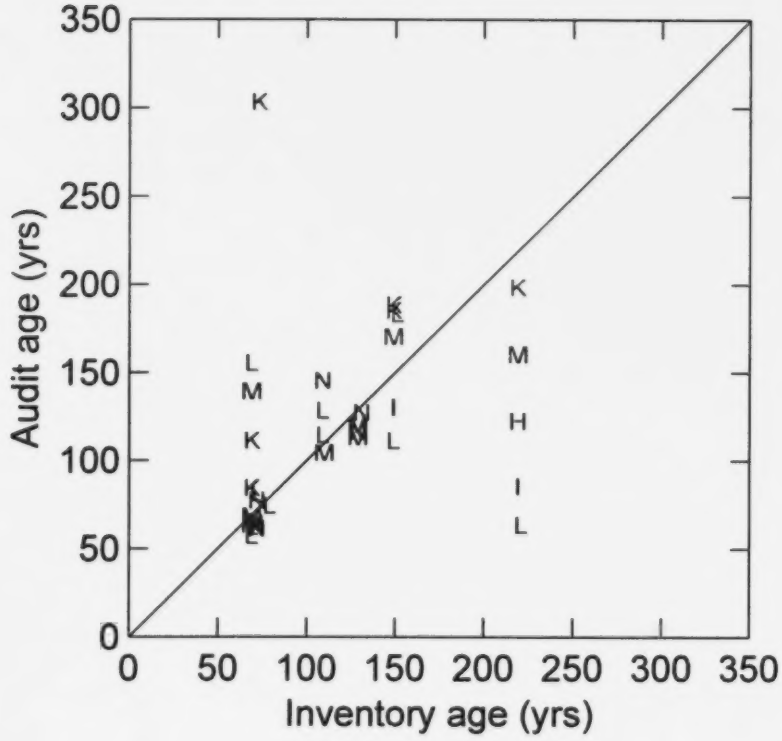
CASSIAR TSA -- Dease Lake North:
Audit Height vs. Inventory Height (by GTG)
(mean difference = -2.7 m; p < 0.001; n=36)



Letter symbols correspond to map label GTG's as follows:

F	*H, H Decid.*	K	*S Pl , S Decid.*
G	*HF,HL,HPy,HPw,HPl,HC,HB,HS*	L	*pure Pl or Pa*
H	*B, BH, BS,BF,BPw,BPl,BL,BPy,BDecid.*	M	*Pl F, Pl Py,Pl L,Pl Pw,Pl S,Pl B,Pl H,PlC*
I	*pure S*	N	*Pl Decid.*
J	*SF,SL,SPw,SPy,SH,SC,SB,SPl*	P	*Dr Decid, Mb, E, At Decid.*

CASSIAR TSA -- Dease Lake North:
Audit Age vs. Inventory Age (by GTG)
(mean difference = 0.3 yrs; p = 0.979; n=36)

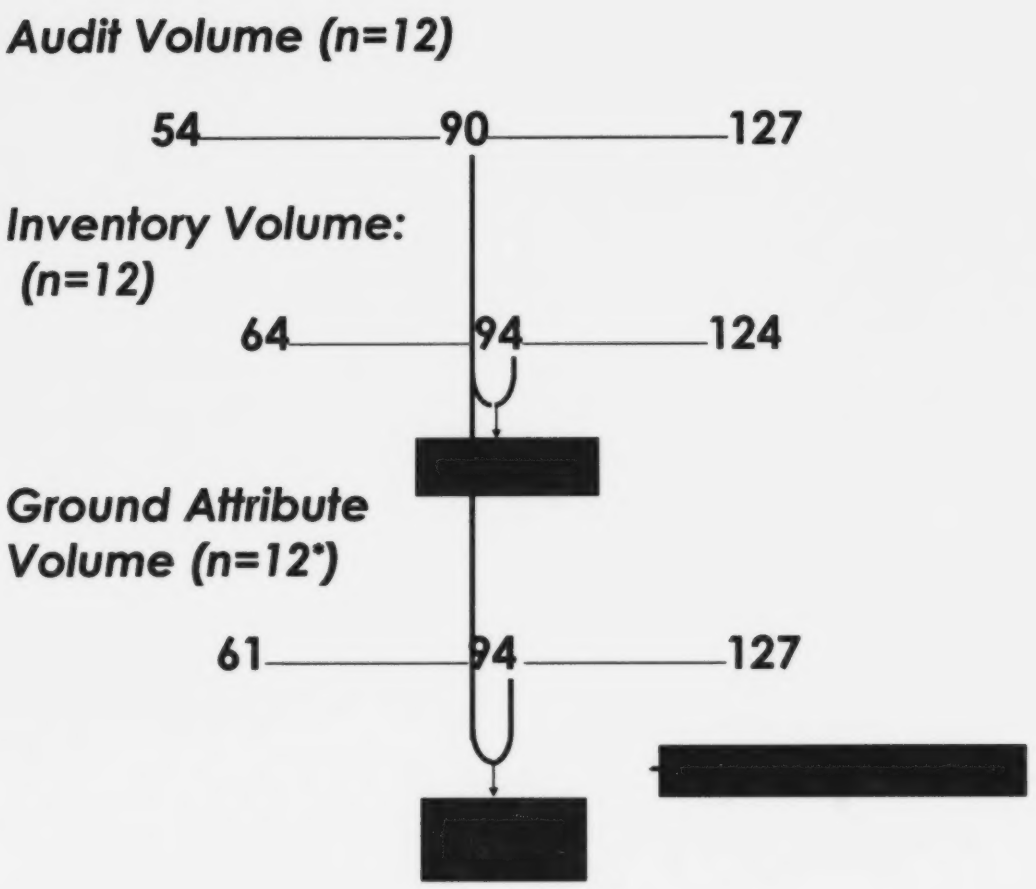


Letter symbols correspond to map label GTG's as follows:

F	*H, H Decid.*	K	*S Pl , S Decid.*
G	*HF,HL,HPy,HPw,HPl,HC,HB,HS*	L	*pure Pl or Pa*
H	*B, BH, BS,BF,BPw,BPl,BL,BPy,BDecid.*	M	*Pl F, Pl Py,Pl L,Pl Pw,Pl S,Pl B,Pl H,PlC*
I	*pure S*	N	*Pl Decid.*
J	*SF,SL,SPw,SPy,SH,SC,SB,SPl*	P	*Dr Decid, Mb, E, At Decid.*

Inoperable

(includes Alesk and Kechika Supply Blocks)



* "Ground attribute" volume is calculated from audit sample attributes (i.e. "ground" attributes: stock and stand table estimates of species composition and stocking, and ground-based averages of top height and age), along with crown closure taken from the original map label, using the VDYP yield prediction model. The difference between the ground attribute volume estimate and the audit volume estimate *approximates* the bias associated with the yield model. The difference between the ground attribute volume estimate and the inventory volume estimate *approximates* the bias associated with the inventory classification attributes. These two bias components comprise the *total bias* in the inventory.

Inoperable

Audit Volume (Kozak) vs. Inventory Volume (Predicted in VDYP) (n=12)

1. Average Volumes/ha and Confidence Interval @ 95% *(Utilization level : 12.5 cm + net merch. less decay only/Tree Class 1,2)*

54 ——— 90 ——— 127

Audit Volume
(40.4% sampling error)

64 ——— 94 ——— 124

Inventory Volume
(map label attributes predicted in VDYP)
(32.2% sampling error)

2. Ratio Analysis : Ratio of Means @95%

$$R = \frac{\text{average audit volume}}{\text{average inventory volume}} = 0.96$$

1.0
↓

0.66 ——— 0.96 ——— 1.27

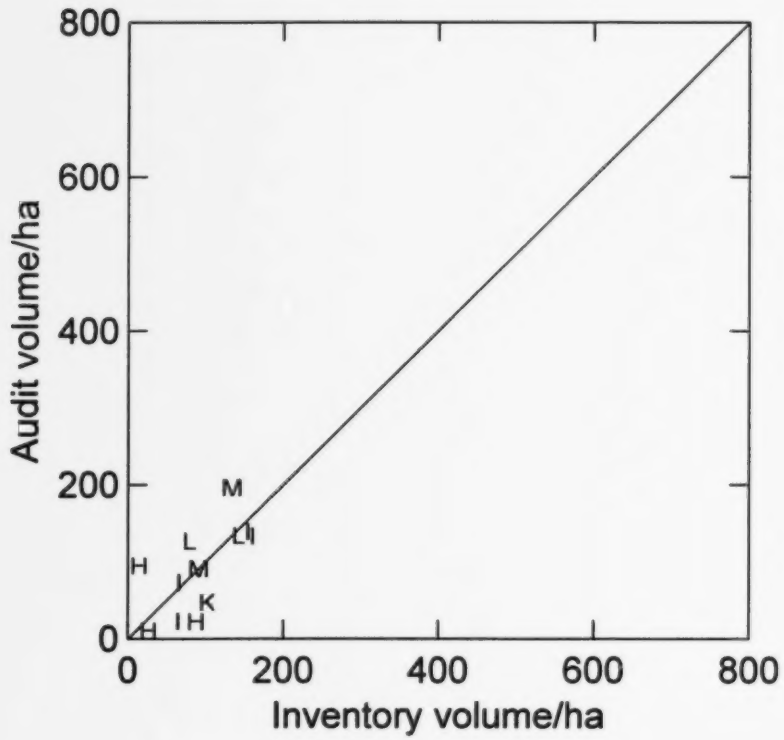
** Since 1.0 is within the interval, the ratio indicates that there is no significant difference between the audit volume and the inventory volume.*

3. Paired T Test @ 95% (α=0.05) for all sample polygons
mean difference = -3.358 m^3/ha
p - value for mean difference = 0.803
**since p-value > α, the difference is not significant*

4. Paired T Test @ 95% for all sample polygons by map label GTG
There were no significant differences within any of the GTGs.

5. Correlation @ 95% (α=0.05) for all samples
Correlation co-efficient r = 0.640
p value for correlation co-efficient = 0.025
∴ correlation is significant

Cassiar TSA -- Inoperable:
Audit Volume vs. Inventory Volume (by GTG)
(Tree Class 1 & 2, less decay only, 12.5cm + dbh)



Letter symbols correspond to map label GTG's as follows:

F	*H, H Decid.*	K	*S Pl , S Decid.*
G	*HF,HL,HPy,HPw,HPl,HC,HB,HS*	L	*pure Pl or Pa*
H	*B, BH, BS,BF,BPw,BPl,BL,BPy,BDecid.*	M	*Pl F, Pl Py,Pl L,Pl Pw,Pl S,Pl B,Pl H,PlC*
I	*pure S*	N	*Pl Decid.*
J	*SF,SL,SPw,SPy,SH,SC,SB,SPl*	P	*Dr Decid, Mb, E, At Decid.*

Inoperable

Audit Volume (Kozak) vs. Ground Attribute Volume (Predicted in VDYP): "VDYP model" bias (n=12)

1. Average Volumes/ha and Confidence Interval @ 95% *(Utilization level : 12.5 cm + net merch. less decay only /Tree class 1,2))*

54——90——127 Audit Volume (40.4% sampling error)

61——94——127 Ground Attribute Volume (predicted in VDYP) (35.1% sampling error)

2. Ratio Analysis : Ratio of Means @95%

$$R = \frac{\text{average audit volume}}{\text{average ground attribute volume predicted in VDYP}} = 0.96$$

1.0
↓
0.79——0.96——1.13

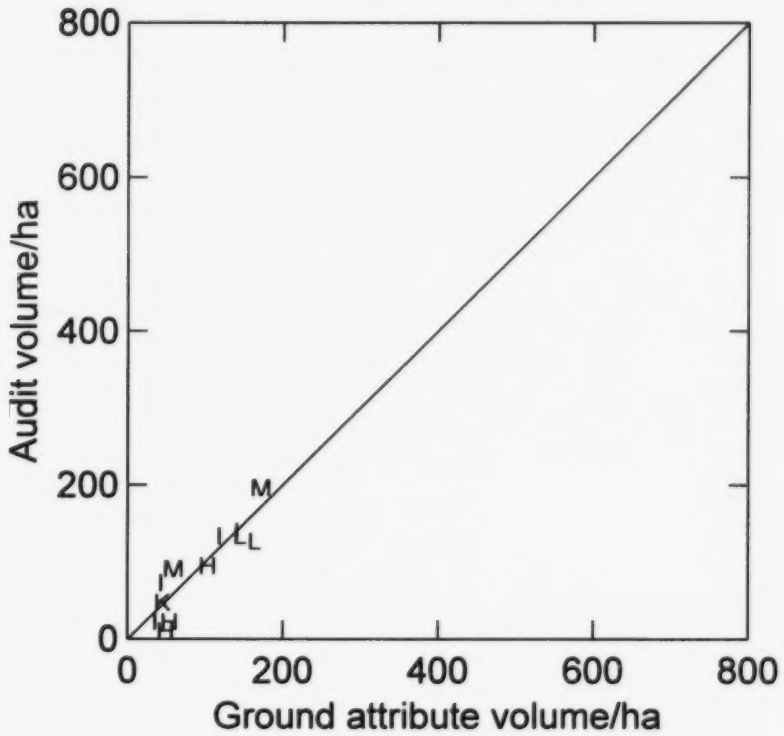
* *Since 1.0 is within the interval, the ratio indicates that there is no significant difference between the audit volume and the ground attribute volume.*

3. Paired T Test @ 95% ($\alpha = 0.05$) for all sample polygons
mean difference = -3.583 m^3/ha
p - value for mean difference = 0.628
**since p - value > α, the difference is not significant*

4. Paired T Test @ 95% for all sample polygons by map label GTG
There were no significant differences within any of the GTGs.

5. Correlation @95%($\alpha = 0.05$) for all samples
Correlation co-efficient r = 0.901
p - value for correlation co-efficient < 0.001
∴ correlation is significant

CASSIAR TSA -- Inoperable:
Audit Volume (Kozak) vs. Ground Attribute Volume (Predicted in VDYP) by GTG
(Tree Class 1 & 2, less decay only, 12.5cm + dbh)



Letter symbols correspond to map label GTG's as follows:

F	*H, H Decid.*	K	*S Pl , S Decid.*
G	*HF,HL,HPy,HPw,HPl,HC,HB,HS*	L	*pure Pl or Pa*
H	*B, BH, BS,BF,BPw,BPl,BL,BPy,BDecid.*	M	*Pl F, Pl Py,Pl L,Pl Pw,Pl S,Pl B,Pl H,PlC*
I	*pure S*	N	*Pl Decid.*
J	*SF,SL,SPw,SPy,SH,SC,SB,SPl*	P	*Dr Decid, Mb, E, At Decid.*

Inoperable

Ground Attribute Volume (predicted in VDYP) vs. Inventory Volume (predicted in VDYP): "Attribute" Bias (n=12)

1. Average volumes/ha and confidence interval @ 95%
(Utilization level : 12.5 cm + net merch. less decay only, Tree Class 1,2))

61——94——127 Ground Attribute Volume (predicted in VDYP) (35.1% sampling error)

64——94——124 Inventory Volume (map label attributes predicted in VDYP) (32.2% sampling error)

2. Ratio Analysis : Ratio of Means @ 95%

$$R = \frac{\text{average ground attribute volume (VDYP)}}{\text{average inventory volume (VDYP)}} = 1.00$$

1.0
↓
0.68——1.00——1.33

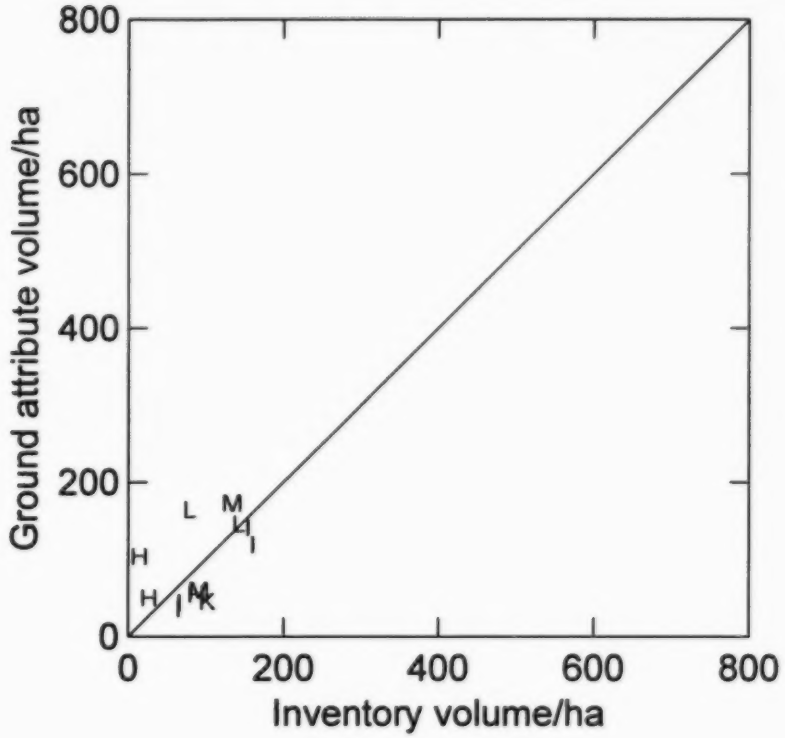
** Since 1.0 is within the interval, the ratio indicates that there is no significant difference between the ground attribute volume predicted in the VDYP and the inventory volume predicted in the VDYP.*

3. Paired T Test @ 95% ($\alpha = 0.05$) for all sample polygons
mean difference = 0.225 m^3/ha
p - value for mean difference = 0.987
**since p - value > α, the difference is not significant*

4. Paired T Test @ 95% for all sample polygons by map label GTG
There was a significant differences within GTG I.
(for GTG I: mean difference = -27.15 m^3/ha; p-value=0.021; n=4)

5. Correlation @95%($\alpha = 0.05$) for all samples
Correlation co-efficient r = 0.531
p - value for correlation co-efficient = 0.076
∴ correlation is NOT significant

CASSIAR TSA -- Inoperable:
Ground Attribute Volume (Predicted in VDYP) vs. Inventory Volume (Predicted in VDYP) by GTG
(Tree Class 1 & 2, less decay only, 12.5cm + dbh)



Letter symbols correspond to map label GTG's as follows:

F	*H, H Decid.*	K	*S Pl , S Decid.*
G	*HF,HL,HPy,HPw,HPl,HC,HB,HS*	L	*pure Pl or Pa*
H	*B, BH, BS,BF,BPw,BPl,BL,BPy,BDecid.*	M	*Pl F, Pl Py,Pl L,Pl Pw,Pl S,Pl B,Pl H,PlC*
I	*pure S*	N	*Pl Decid.*
J	*SF,SL,SPw,SPy,SH,SC,SB,SPl*	P	*Dr Decid, Mb, E, At Decid.*